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(71)(72) Applicant and Inventor: HESLINE, Raymond [AU/AU]; 31 Lilac Street, East Bentleigh, VIC 3165 (AU).

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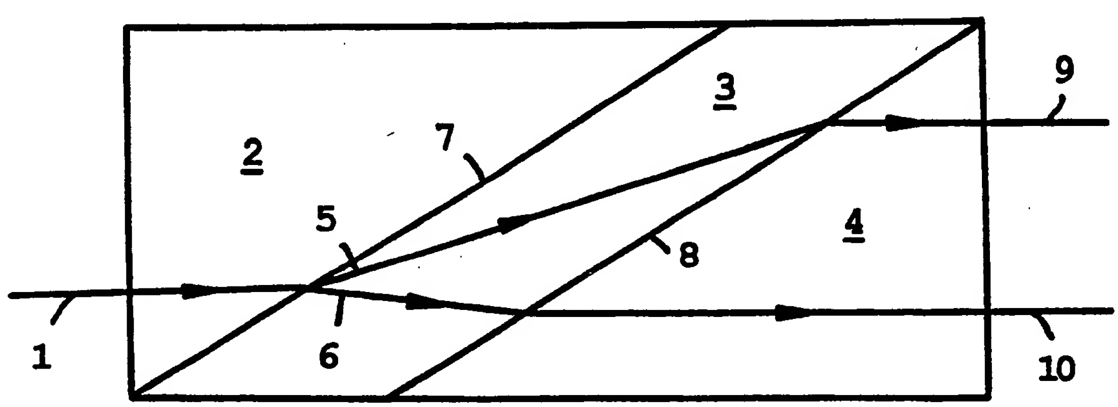
(54) Title: BIREFRINGENT POLARIZING DEVICE



(57) Abstract

A birefringent polarizing device which separates a beam (1) into polarized component beams (9) and (10) by transmitting both components through plane parallel element (3). Separation occurs since one or both of plane parallel element (3) and element (2) is birefringent. Elements (2) and (4) are of the same refractive index or indices so that beams (9) and (10) emerge parallel to one another. Plane parallel element (3) may also be a space (3) which allows the device to be used with high powered lasers. Many variants are described.

* See back of page

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BIREFRINGENT POLARIZING DEVICE

Technical Field

This invention relates to birefringent polarizers and polarizing beam-splitters and particularly to birefringent polarizers and polarizing beam-splitters which separate polarization components by transmitting both components through an interface.

Background Art

Many polarizers and polarizing beam-splitters are known to the art, each having disadvantages.

The Glan-Thompson polarizer, which is a block of birefringent material cut into prisms and then cemented together acts by reflecting one polarization component at the cement interface and by transmitting the other. The device requires a considerable amount of birefringent material, generally calcite, which is scarce and expensive, and is unable to work with high powered lasers and ultraviolet light, since the light destroys or clouds cement.

The Glan-Thompson polarizing beam-splitter, which makes use of the reflected polarization component, suffers from the added disadvantage that polarized beams exit said device at inconvenient angles, for example 45 degrees, when it is often useful that beams are parallel, orthogonal or otherwise oriented.

The Glan-Taylor polarizer which is similar to the Glan-Thompson polarizer but uses an air space instead of cement to separate polarization components can work with many light sources but suffers from reflection loss and ghosting caused by the air gap.

The Wollaston, Rochon and Senarmont beam-splitters, which separate polarization components by transmitting said components through an interface, permit optical contacting for use with most light sources, but produce beams which also exit

at inconvenient angles, with one or both polarization components suffering from chromatism and distortion.

The double refracting element (beam displacer), which produces accurately parallel polarized beams of light, achieves small beam separation and limited field. Also, since the beams may pass through a considerable amount of material before achieving useful separation, then wavefront distortion can occur in the extraordinary beam, due to imperfections in the crystal's structure. See, for example, "Birefringence of Quartz and Calcite," Journal of the Optical Society of America, volume 49, number 7, July 1959, pages 710-712). Beam separation can be further limited by the small size and high cost of suitable crystals.

Polarizing prisms and their various defects are described in detail by H. E. Bennett and J. M. Bennett, "Polarization," in Handbook of Optics, W. G. Driscoll and W. Vaughan, Editors, McGraw-Hill, New York, 1978.

Disclosure Of The Invention

It is an object of this invention to provide a birefringent polarizing beam-splitter in which polarized beams of electromagnetic radiation may emerge from the device being free from chromatism and distortion and such that angular separation may be greater than for a double refracting element.

It is also an object of the invention to provide a polarizing beam-splitter in which polarized beams of electromagnetic radiation may emerge from said device being oriented at convenient angles.

It is another object of the invention to provide a polarizing beam-splitter which may be conservative in the use of birefringent material.

It is a further object of the invention to provide a beam displacer which may causes less wavefront distortion in the extraordinary beam than a known birefringent beam displacer.

It is a still further object of the invention to provide an improved polarizer.

To this end, in accordance with the invention, the birefringent polarizing device is characterised by a space or an element which is all or in part plane parallel, situated between at least two optical elements, wherein polarization components are separated by the transmission of said components through an interface, with at least one element forming said interface being birefringent.

Isotropic elements on either side of said element which is all or in part plane parallel have the same refractive index, birefringent elements on either side of said space or element which is all or in part plane parallel have the same optic axis orientations, and when elements on either side of said space or element which is all or in part plane parallel are at least one isotropic and at least one birefringent, then the refractive indices of said isotropic element or elements match an index or indices of said birefringent element or elements.

Birefringent elements on either side of a space may be Brewster prisms with different optic axis orientations, as in the two elements of a Wollaston, Rochon or Senarmont prism, so that said prisms may permit the transmission of one polarization component without Fresnel reflection. These prisms may be in physical contact without being in optical contact, thus having air between them, eliminating stress birefringence between elements and removing the accurate polishing requirement. One Brewster prism may also be isotropic.

In the case of a polarizer, the unused polarization component may be reflected as well as transmitted at an interface so as to provide a large acceptance angle.

Also reflecting surfaces or Brewster windows may be included in said device to translate a polarization component or components.

Brief Description Of Drawings

Fig. 1 represents an embodiment in accordance with the invention describing the method in which a beam-splitter with a plane parallel element operates.

Fig. 2 represents a particular embodiment in accordance with the invention being a beam-splitter which uses the Wollaston prism beam-splitting method to obtain polarized components.

Fig. 3 represents an embodiment in accordance with the invention being a beam-splitter in which at least one element is isotropic, being an embodiment which is economical in its use of birefringent material.

Fig. 4 represents an embodiment in accordance with the invention being a beam-splitter in which the second element is plane parallel only in part.

Fig. 5 represents an embodiment in accordance with the invention being a polarizer which provides a large acceptance field.

Fig. 6 represents an embodiment in accordance with the invention, being an extension of the three element Wollaston, producing output beams which are parallel and free from chromatism and distortion.

Fig. 7 represents an embodiment in accordance with the invention being a beam-splitter in which polarization components exit at orthogonal angles.

Fig. 8 represents an embodiment in accordance with the invention being a beam-splitter which includes an air space.

Fig. 9 represents an embodiment in accordance with the invention being a beam-splitter wherein Brewster prisms are used to reduce reflection loss for one polarization component.

Fig. 10 represents an embodiment in accordance with the invention being a plain polarizer which includes Brewster prisms.

Fig. 11 represents an embodiment in accordance with the invention being a polarizer similar to the previous

embodiment in which beams are reflected from a mirror to counter displacement.

Fig. 12 represents an embodiment in accordance with the invention being a polarizer in which two mirrors are employed to counter image inversion.

Fig. 13 represents an embodiment in accordance with the invention being a polarizer which employs the Rochon prism beam-splitting method and includes Brewster prisms.

Fig. 14 represents an embodiment in accordance with the invention similar to the previous embodiment, in which both polarization components are transmitted through the last face of the second prism.

Fig. 15 represents a beam displacer, similar to a known beam displacer made of calcite, in which the amount of calcite is reduced by replacing a substantial section of said beam displacer with isotropic material.

Figure 16 represents an embodiment using 45 degree calcite prisms, wherein beams emerge orthogonal to one and other.

Figure 17 represents an embodiment similar to the embodiment in figure 16, wherein beams exit at an angle of 120 degrees.

Description Of Preferred Embodiments

Fig. 1 represents an embodiment in accordance with the invention describing how a beam-splitter which includes a plane parallel element operates, in which a beam of electromagnetic radiation 1 enters first element 2 and passes into second element 3, which in this case is the plane parallel element, so that beam 1 separates into orthogonally polarized beams 5 and 6.

Since at least element 2 or element 3 is double refracting, the beams will separate by encountering different refractive indices as known, for example, in the Wollaston prism (Bennett and Bennett, page 10-60). Similar separation also occurs when one of said elements is isotropic.

The refractive indices of elements on either side of element 3 are the same for the same polarization components, and so once beams 5 and 6 have passed through element 3, with faces 7 and 8 parallel, said beams will pass into element 4 parallel to related components in 2.

After leaving element 4 component beams become beams 9 and 10 which are parallel to each other and parallel to input beam 1, being free from chromatism and distortion.

Figure 2 represents a particular embodiment in accordance with the invention being a beam-splitter based on the Wollaston prism beam-splitting method.

Beam 21 enters double refracting prism 22 with its optic axis 25 in the plane of the drawing and parallel to input face 30. Beam 21 becomes beam 26 in prism 22 where said beam then passes into plane parallel element 23, being a double refracting element with its optic axis 27 normal to the plane of the drawing. Said beam 26 then becomes orthogonally polarized beams 28 and 29, as known.

Now, beams 28 and 29 continue through interface 32 and into double refracting prism 24, with its optic axis 33 in the same direction as optic axis 25, such that beams refract to become parallel to related beams in 22. As beams 28 and 29 are parallel to component beams 26, and given that faces 30 and 31 are plane parallel, then beams 37 and 38 exit element 24 parallel to input beam 21.

Block 34, formed by extending the dotted lines, can represent a Wollaston prism. Since Wollaston prisms are commonly manufactured with extinction ratios in excess of 10^5:1, and since beams in the described embodiment exit as if from a Wollaston prism, then extinction ratios should be similar to those of the Wollaston prism or better. Note, beams travel through the equivalent of two Wollaston prisms in sequence.

By covering surfaces 35 and 36 with an absorbing material, as is done with the Glan-Thompson prism, reflected light can be removed from the device.

Calcite, which is generally the double refracting material used in constructing Wollaston prisms, has a large

positive coefficient of expansion parallel to the optic axis and a smaller negative coefficient of expansion perpendicular to the optic axis. When the two parts of a Wollaston prism are then joined together a considerable amount of strain may generate in each prism when the temperature changes. This strain, which can produce strain birefringence, still permits excellent extinction in output component beams. The same event should thus occur in the described embodiment.

Similar embodiments may be constructed based upon Rochon and Senarmont prism beam-splitting methods. Further embodiments may also be constructed based upon known three beam-splitting methods with optic axes reversed as, for example, in said described embodiment wherein elements 22 and 24 have optic axes normal to the plane of the paper, and element 23 has its optic axis in the plane of the drawing parallel to input face 30. Other optic axis orientations may also be used to advantage.

Calcite is a scarce and expensive material, hence polarizing devices which reduce the amount of calcite or other birefringent material required are desirable.

In figure 3 elements 41, 43 and 44 may be isotropic while element 42 is birefringent, or 42 may be isotropic while 41, 43 and 44 are birefringent, reducing the amount of birefringent material employed. Also element 41 may be double refracting while elements 42, 43 and 44 may be isotropic, with refractive indices of elements 43 and 44 matching those of element 41. In this last case chromatism and distortion could appear in one of the output beams and so its use would be appropriate where imaging is not required. Other variations which include designs in figures 1 and 2 will also be obvious.

Figure 4 represents an embodiment in accordance with the invention in which beams 53 and 54 leave said embodiment at different angles. Element 51 is double refracting and elements 52 and 53 are isotropic, with refractive indices of elements 52 and 53 matching those of element 51. Element 52 could be, for example, injection moulded.

Figure 5 represents an embodiment in accordance with the invention being a polarizer only, constructed so that

unwanted components may be transmitted as well as reflected at interface 74.

Beam 75 passes through prism 71 so that unwanted component 76 is reflected from surface 74 and wanted component 77 is transmitted through surface 74. Transmitted beam 77 then passes into element 73 leaving the device as beam 78.

For beam 79, in which both polarization components are transmitted, unwanted component 80 passes through element 72 so as to separate from wanted component 81. Wanted component 81 passes into element 73 and out of the polarizer as beam 82.

As unwanted components may be transmitted as well as reflected, the described device will permit a larger optical acceptance angle than is obtained with the Glan-Thompson polarizing prism.

Figure 6 represents an embodiment in accordance with the invention which operates such that beams are separated in element 91, and further separated in plane parallel element 92; the embodiment being an extension of the three element Wollaston prism (Bennett and Bennett, page 10-61). Parallel beams are produced which are free from chromatism and distortion.

Fig. 7 represents an embodiment in accordance with the invention in which polarization components exit said embodiment at orthogonal angles. In this embodiment the Rochon beam splitting method is employed. Beam 94 is reflected from face 95 so as to exit the device as beam 96 being orthogonal to beam 97.

If a quarter waveplate is placed at position 98 then beam 96, when passed through said device in the reverse direction, will pass through waveplate 98. On being reflected back through said waveplate said beam will return through said embodiment as beam 97.

Glan-Taylor and Glan-Focault polarizers, which consist of birefringent prisms separated by an air gap, work by transmitting one polarization component at said gap and by reflecting the other component. A problem with this type of polarizer is that reflection loss occurs at the air gap along

with ghosting. By allowing both polarization components to be transmitted it is possible to reduce this reflection loss and also to provide a polarizing beam-splitter which has the advantages of an air spaced polarizer.

Fig. 8 represents an embodiment in accordance with the invention comprising two birefringent prisms and an air space. As shown, beam 100 enters prism 101 and is split at face 102 into orthogonally polarized beams 103 and 104. Said beams, after travelling through the air space, pass into prism 105. In this embodiment prisms 101 and 105 have the same optic axis orientations and faces 102 and 106 are parallel, so beams 103 and 104 will enter prism 105 and exit said prism as parallel beams 107 and 108. Thus in passing through the two prisms input beam 100 will be separated into parallel, orthogonally polarized output beams 107 and 108.

If the optic axes of the elements are normal to the plane of the drawing, as with a Glan-Focault prism, then, in the drawing, the upper beam will suffer smaller reflection loss than the lower beam. This is because the electric field of the upper beam is parallel to the plane of incidence, being P polarization, which in this case passes through the interface close to or at Brewster's angle. By also coating hypotenuse faces with antireflection films, reflection loss at said faces can be reduced for the other polarization component.

Fig. 9 represents an embodiment in accordance with the invention being a polarizer in which reflection loss at every faces, as calculated from Fresnel's equation, is reduced to zero for one polarization component. In this embodiment beam 112 enters prism 110 and is split into orthogonally polarized components 113 and 114. These components then pass into prism 111. If the optic axes of said prisms 110 and 111 are oriented normal to the plane of the drawing, beam 112 will become parallel beams 115 and 116 with beam 116 being the ordinary beam which passes through each prism at Brewster's angle.

Other enbodiments could transmit the extraordinary beam.

Fig. 10 represents an embodiment in accordance with the invention, similar to the previous embodiment, being a polarizer which uses Brewster prisms.

Beam 120 passes through prism 121 with the P polarized component passing through prism 122 at Brewster's angle. The S polarized component meets stop 123.

Fig. 11 represents an embodiment in accordance with the invention being a polarizer wherein component beams are reflected from mirror 130 so as to counter displacement which occurs in the preceding embodiment. This is the previous embodiment with prism 122 reflected about said mirror.

Fig. 12 represents an embodiment in accordance with the invention being a polarizer in which a further reflection occurs at second mirror 140 so as to prevent the image from being inverted and to keep output beam 142 parallel to input beam 141.

Fig. 13 represents an embodiment in accordance with the invention being a polarizing device similar to the Rochon prism, which includes Brewster prisms.

In this embodiment beam 150 is separated into orthogonally polarized beams 153 and 154, with the P polarized component 154 passing through both prisms at Brewster's angle and the S polarized component 153 being totally reflected at last face 155. Here the optic axis orientation of the first element 151 is normal to the plane of the drawing so that beam 154 is the ordinary beam. The optic axis of the second element 152 is in the plane of the drawing parallel to the P polarized beam in the element. Prism 152 could be replaced with a glass prism having an index of refraction matching that of the ordinary ray in prism 151. Some glasses of said index are described by E. O. Ammann and G. A. Massey, Journal of the Optical Society of America, volume 58, number 11, 1968, pages 1472-1433.

Fig. 14 represents an embodiment in accordance with the invention similar to the previous embodiment but wherein the S polarized component is transmitted through the last face instead of being reflected from said face.

In the embodiment second prism 161 has its optic axis normal to the plane of the drawing and the first prism 160 may be glass. The S polarized beam is transmitted through face 162.

Since prisms in the previous two embodiments are not cemented or optically contacted then strain between elements is removed. Note, these prisms could be in physical contact and still be considered air spaced.

Fig. 15 represents a beam displacer, similar to a known calcite beam displacer, wherein the amount of calcite is reduced by replacing a substantial section of said beam displacer with isotropic material.

In the embodiment elements 170 and 172 are 45 degree calcite prisms with optic axes oriented normal to the plane of the drawing, and element 171 is an isotropic plane parallel element with a refractive index similar to that of the extraordinary beam in calcite.

In said known beam displacer beam separation is 6.2 degrees. In this embodiment beam separation is 7.1 degrees. If elements 170 and 172 are optically contacted to element 171, Fresnel reflection at surface 173 will be less than 0.03 percent for the P polarized component and zero for the S polarized component. This is because the P polarized component passes through the interface at an angle close to Brewster's angle.

For said embodiment, wavefront distortion in the extraordinary beam can be reduced by about 80 percent, as can the amount calcite. This permits the construction of large beam displacers. Note, calcite can be further reduced as shown in figure 3.

Figure 16 represents an embodiment using 45 degree calcite prisms, wherein beams emerge orthogonal to one and other.

Prisms 180 and 182 have optic axes normal to the plane of the drawing and element 181 is isotropic with a refractive index similar to that of the extraordinary ray in calcite, as in the previous embodiment. Section 183, shown by dotted lines, which would normally be the upper section of the previously described beam displacer, is here the section below

reflecting surface 184. Beam 186 will leave prism 182 as if from said section 183, being free from chromatism and distortion.

This embodiment can be used with high powered light sources if optical contacting is employed and the amount of calcite and wavefront distortion in the extraordinary beam can be further reduced.

Figure 17 represents an embodiment similar to embodiment 16, wherein beams exit at an angle of 120 degrees to one and other.

In this embodiment prism 190 is a 60 degree right prism, and element 192 is modified so that polarization component 195 may leave said element free from chromatism and distortion.

The orientation of face 193 is determined by reflecting the supposed upper section of a beam displacer about reflecting surface 194, reflecting surface 194 being orthogonal to faces of plane parallel element 191.

Elements 190, 191 and 192 may be calcite, or said elements may be combinations of calcite and other material, for example synthetic fused silica or Schott optical glass BK 7.

Further embodiments using other birefringent materials will be evident.

In each embodiment which includes a plane parallel element, little restriction is placed upon cements which may be used and optical contacting may also be employed. Steel, Smartt and Giovanelli have successfully contacted glass and calcite (Australian Journal of Physics, volume 14, 1961, page 209), and since it is difficult to produce surfaces of the required flatness in prisms (F. Twyman, "Prism and Lens Making," second edition, Hilger & Watts, London, 1952) then in these embodiments the first and third elements could be polished to required flatness as plane parallel sections, later being divided to provide separate elements.

Many modifications and variations to the described embodiments will be apparent to those skilled in the art and all such modifications and variations should be considered as within the scope of the present invention.

CLAIMS

1. A birefringent device for polarizing light which separates polarization components by transmitting said components through an interface, characterised by:

a space or an element which is all or in part plane parallel situated between at least two optical elements wherein;

isotropic elements on sides of said element which is all or in part plane parallel have the same refractive index and wherein;

birefringent elements on sides of said space or element which is all or in part plane parallel have the same optic axis orientations and wherein;

isotropic and birefringent elements on sides of said space or element which is all or in part plane parallel have an isotropic element or elements which match an index or indices of said birefringent element or elements and wherein;

birefringent Brewster prisms on sides of said space may have different optic axis orientations so that said prisms may permit the transmission of one polarization component without Fresnel reflection and wherein;

a birefringent Brewster prism on one side of said space and an isotropic Brewster prism on the other side of said space may permit the transmission of one polarization component without Fresnel reflection.

2. A device as claimed in claim 1, wherein an unwanted polarization component may be reflected as well as transmitted at an interface.

3. A device as claimed in claims 1 and 2, characterised in that reflecting surfaces or Brewster windows are included to translate a polarization component or components.

4. A device as claimed in claims 1, 2 and 3, wherein additional elements are added to advantage.

5. A device as claimed in claims 1, 2, 3 and 4 characterised in that said device is employed for a purpose other than polarizing light or beam-splitting such as, for example, combining beams.

6. An optical instrument which includes a birefringent polarizing device characterized in that it further includes a device as claimed in claims 1, 2, 3, 4 or 5.

7. Any feature or step or combination of features or steps described herein.

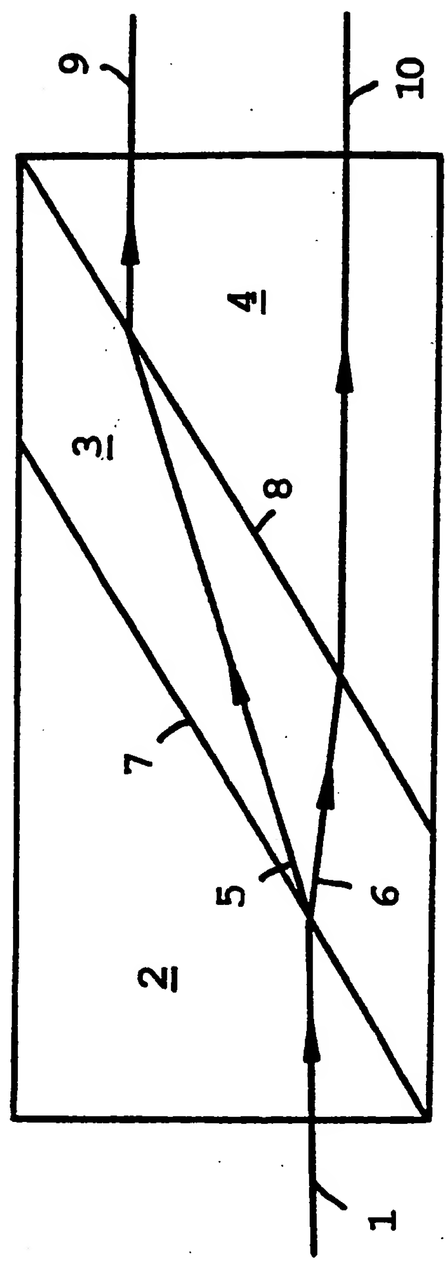

Fig. 1

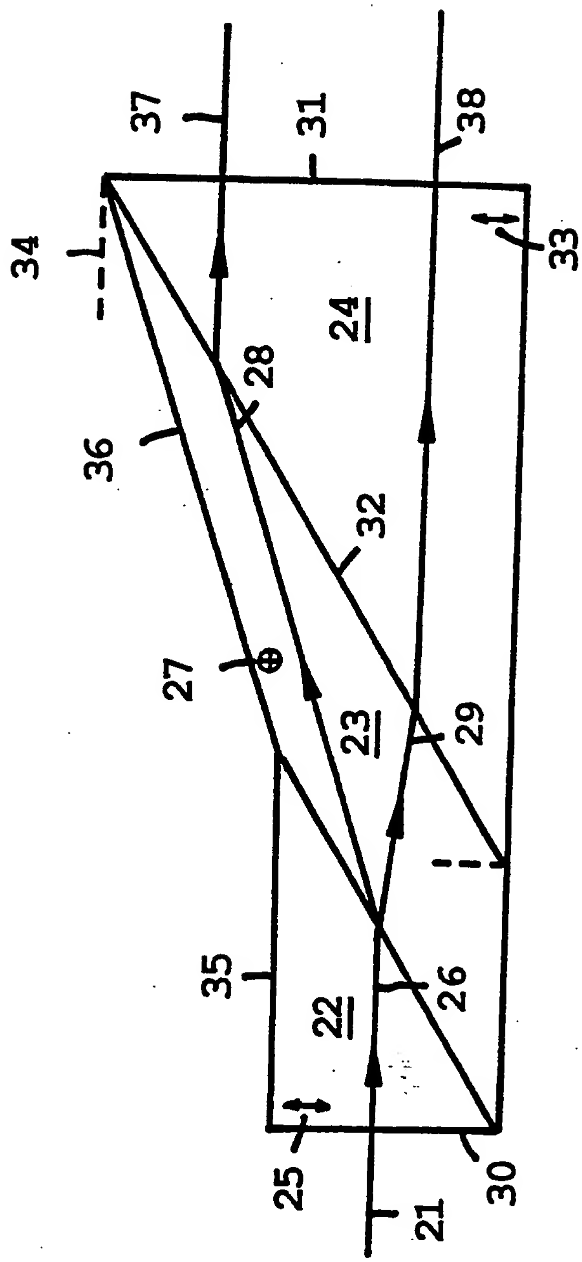

Fig. 2

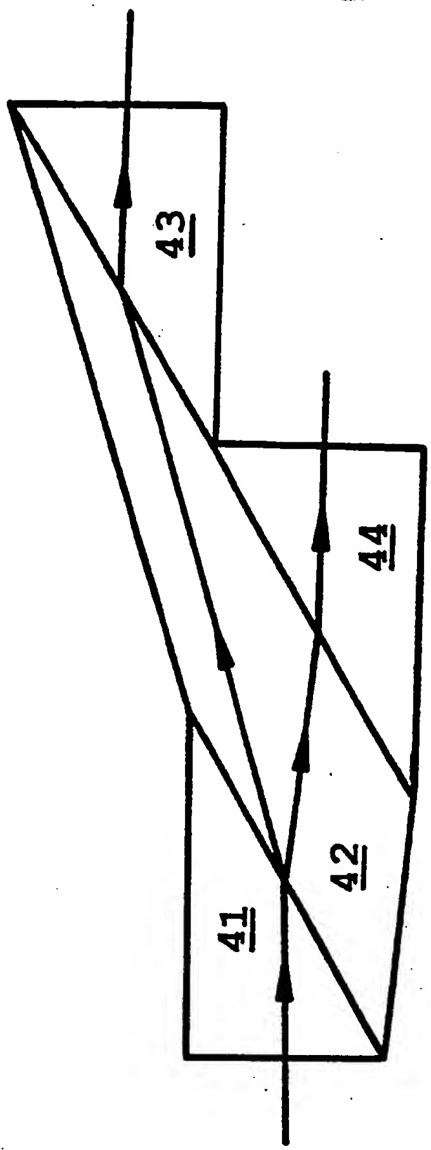

Fig. 3

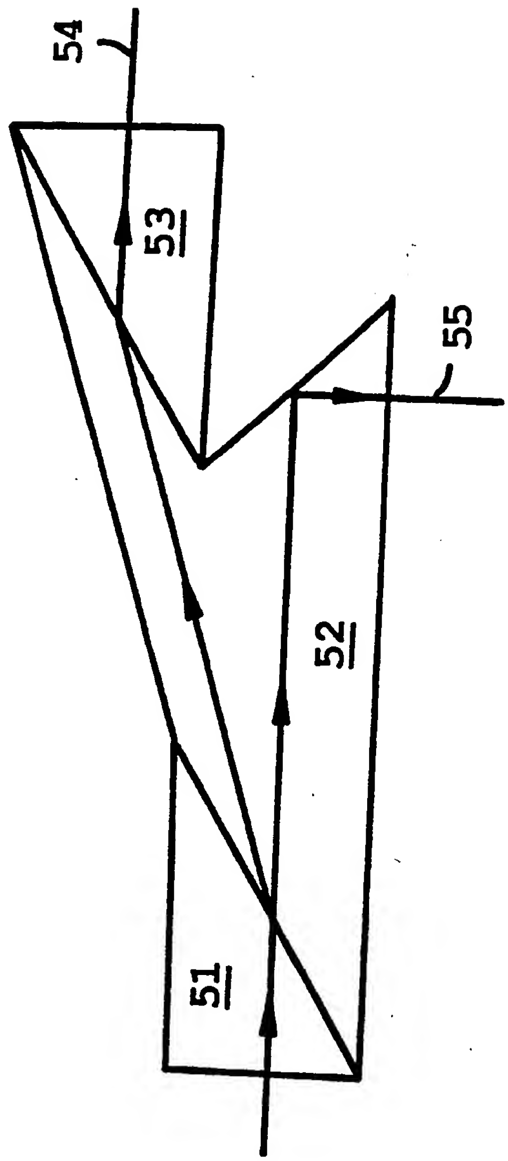

Fig. 4

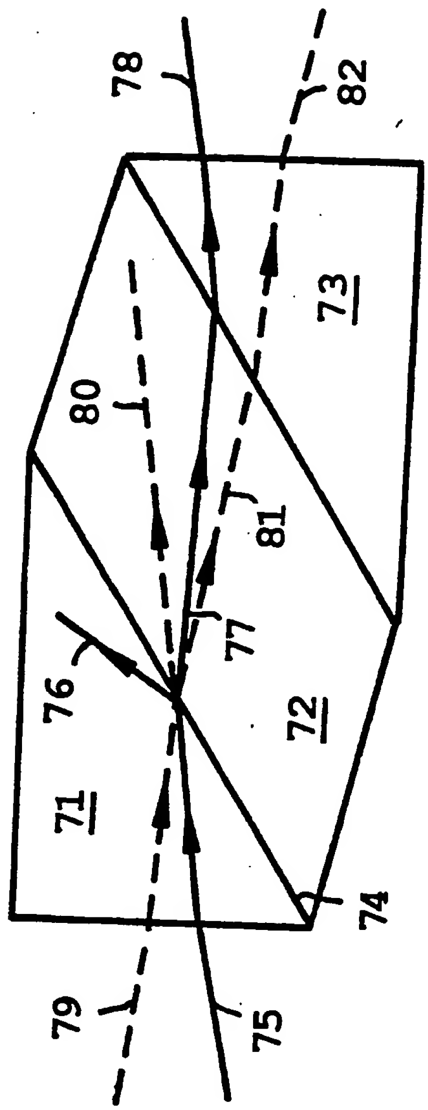

Fig. 5

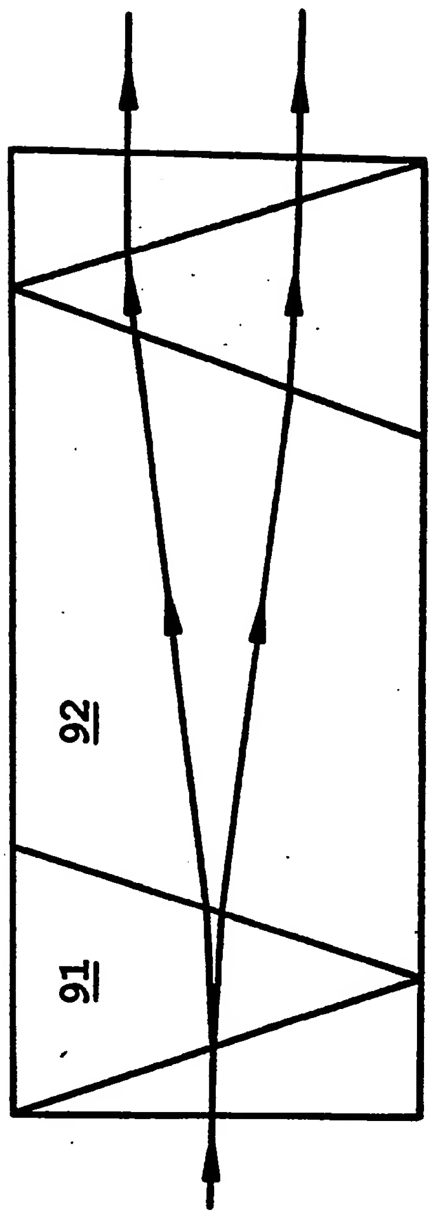

Fig. 6

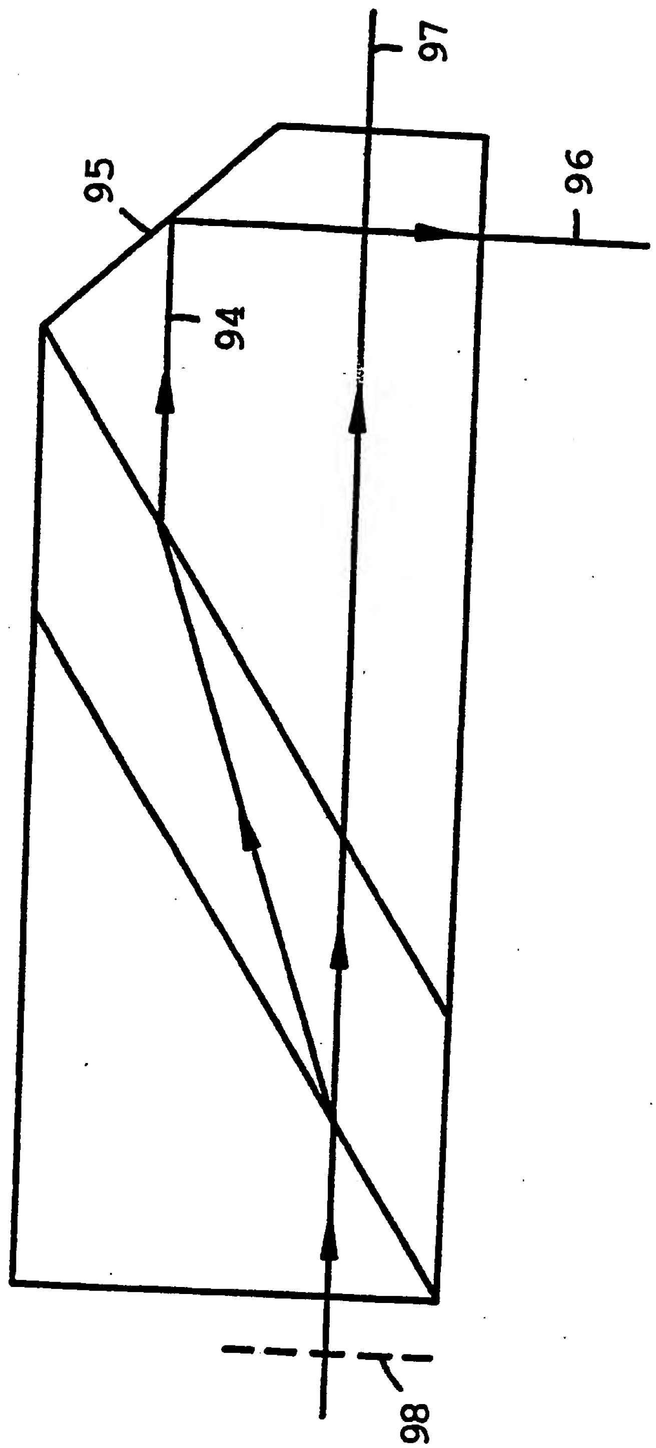

Fig. 7

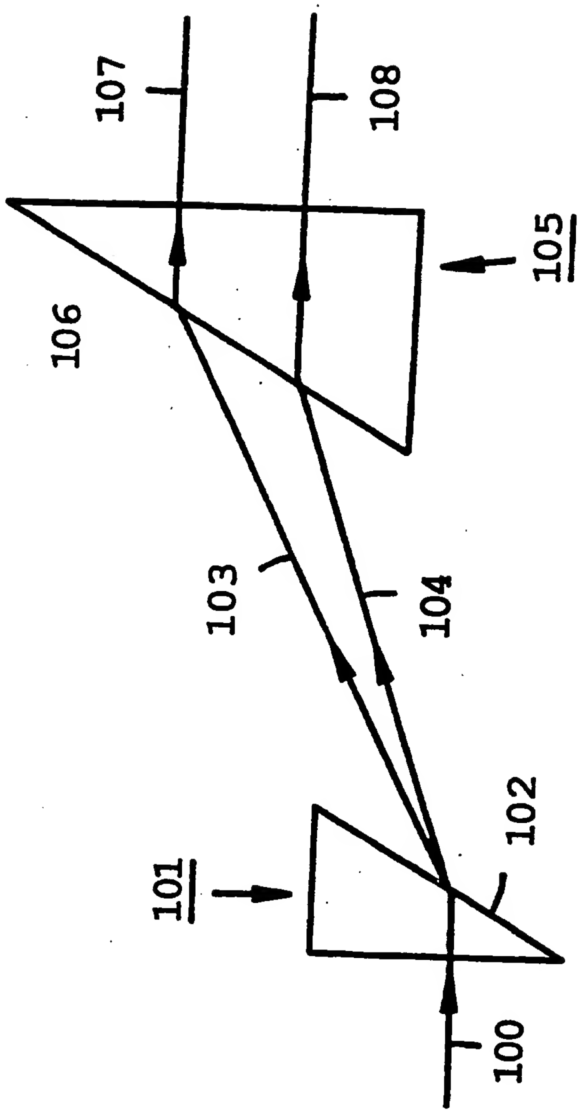

Fig. 8

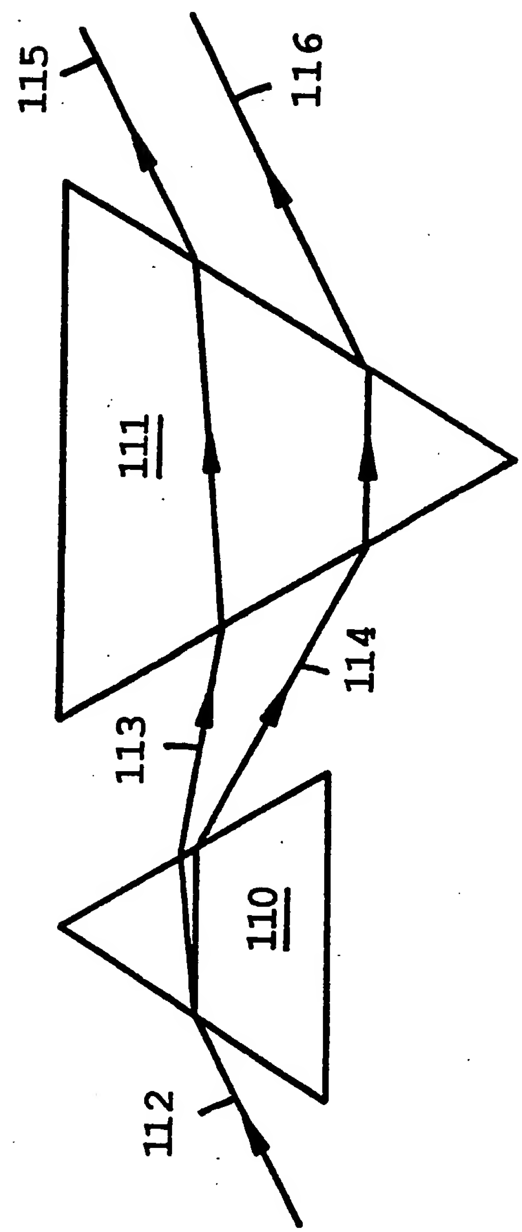

Fig. 9

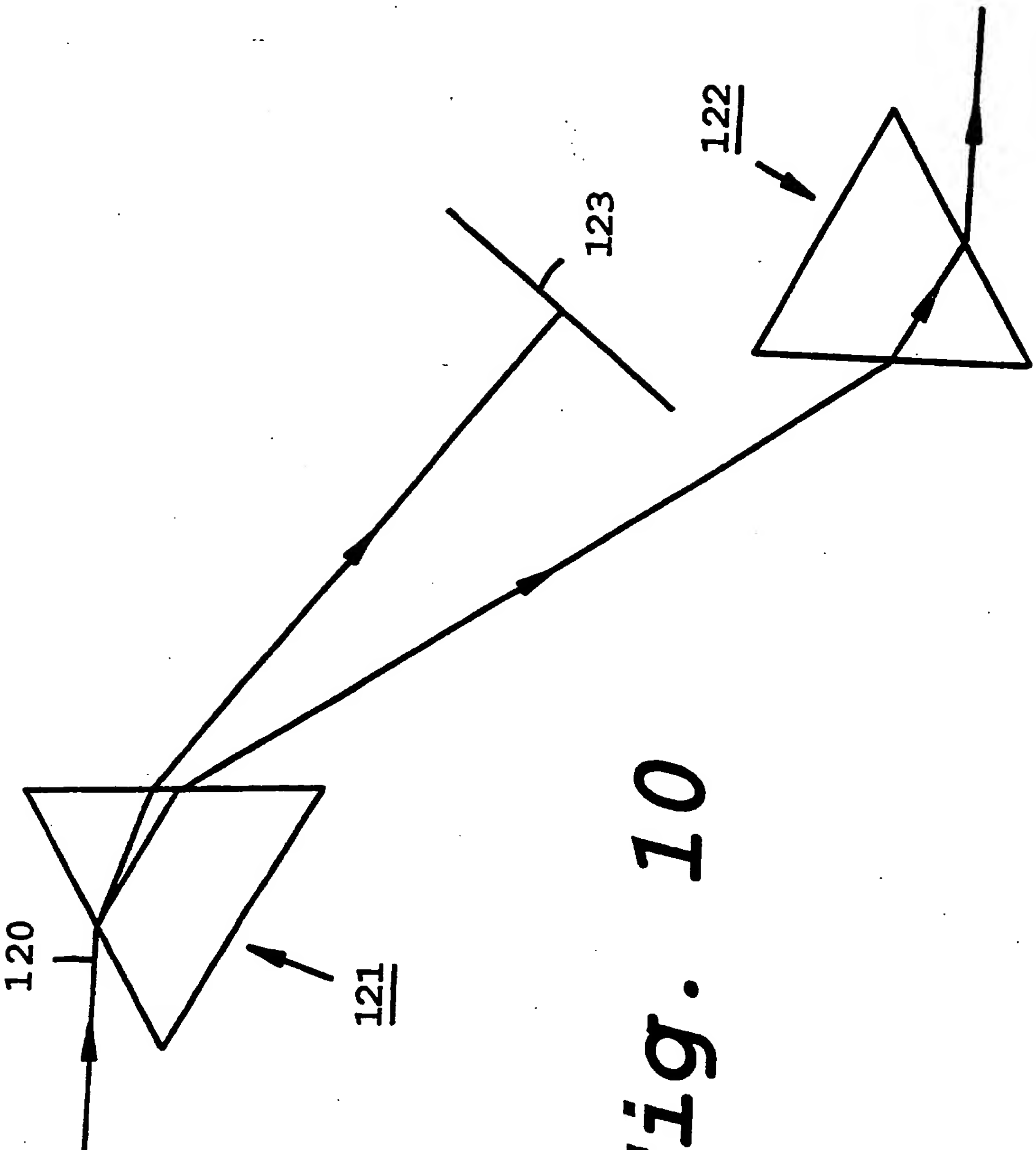

Fig. 10

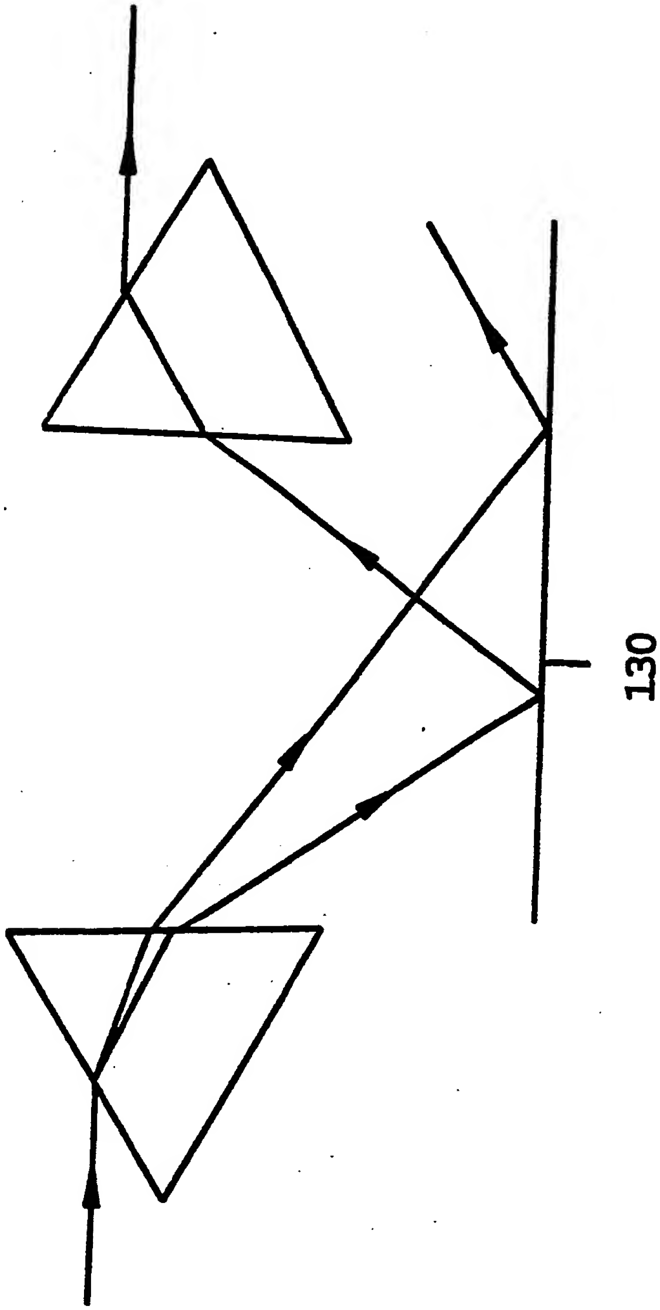

Fig. 11

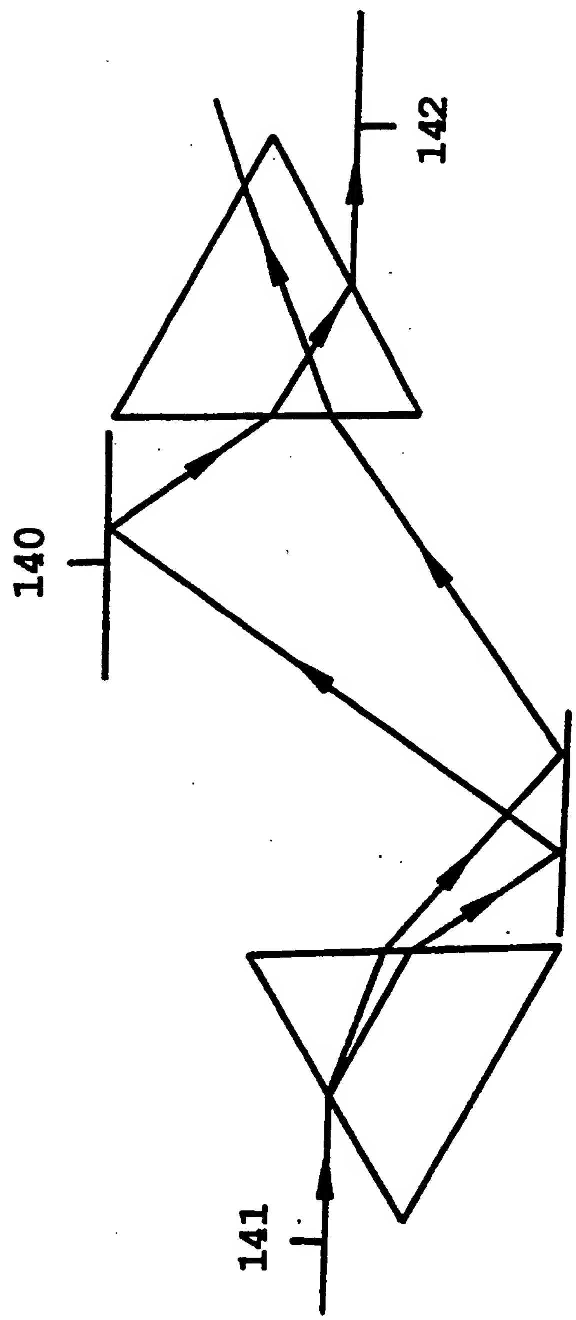

Fig. 12

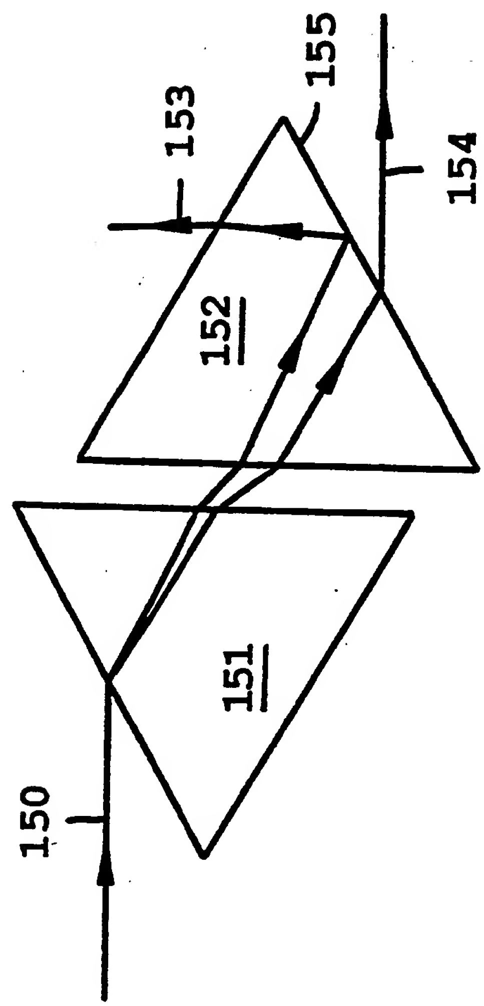

Fig. 13

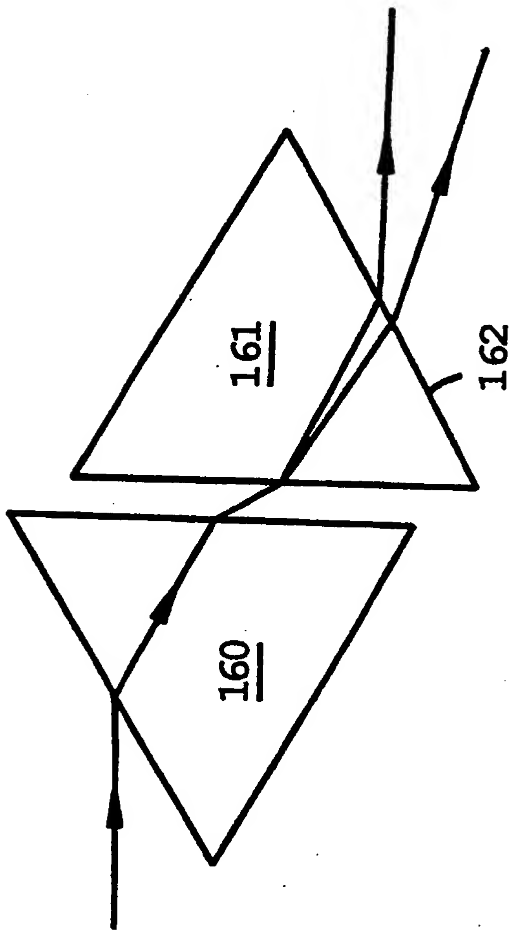

Fig. 14

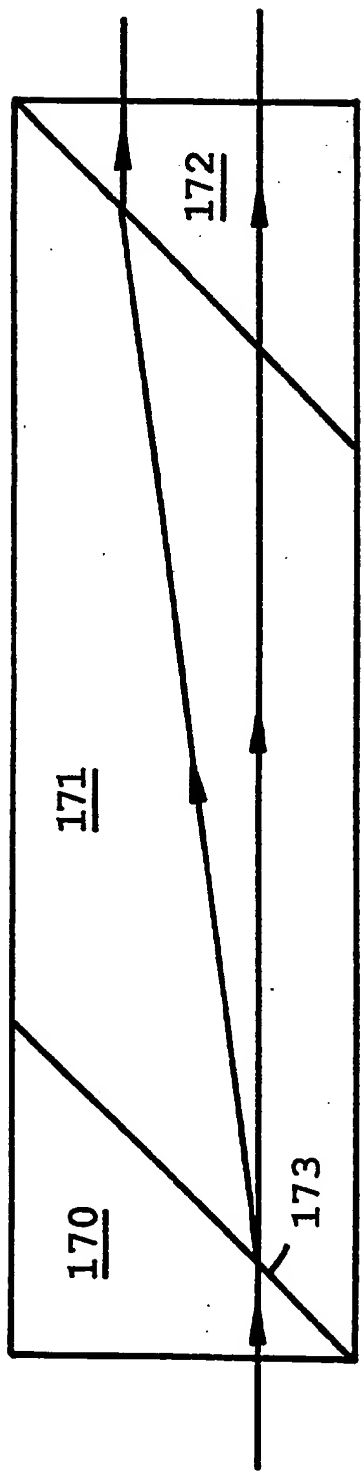

Fig. 15

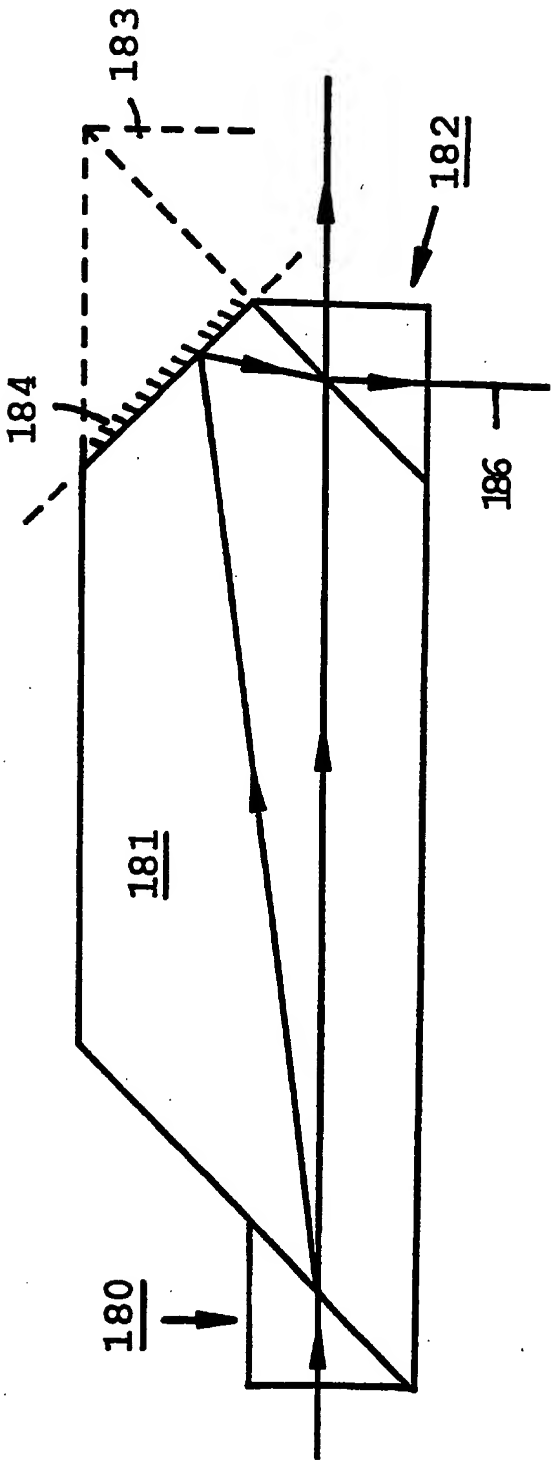

Fig. 16

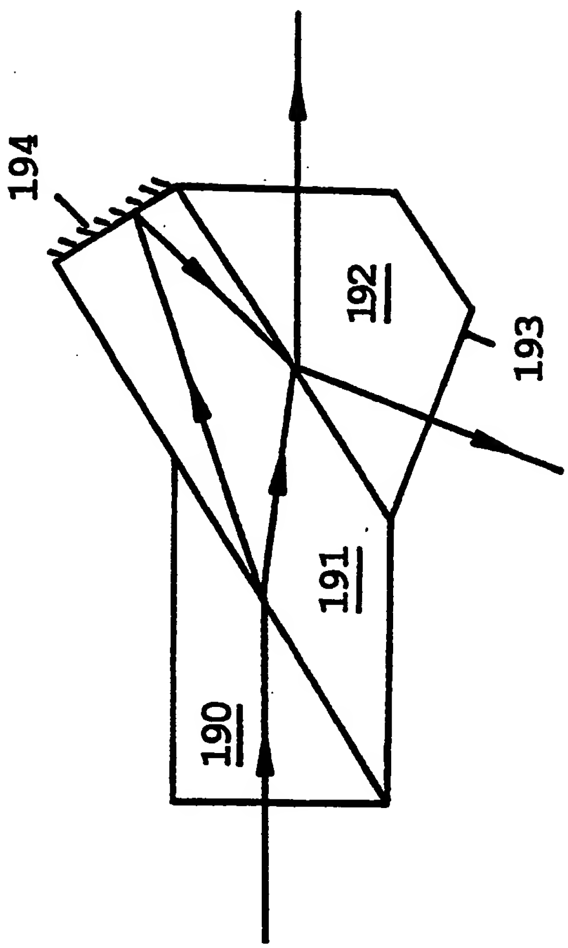

Fig. 17

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00223

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{5} G02B 27/28, 27/12

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	G02B 27/28, 27/12

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above; Australian Classification 00.47

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	AU,B, 1361/66 (400420) (WESTERN ELECTRIC COMPANY, INCORPORATED) 10 August 1967 (10.8.67) (page 4, line 8 - page 7, line 27 and Fig 1)	1, 4, 5, 6
A	AU,B, 64541/74 (471763) (AMERICAN OPTICAL CORPORATION 17 July 1975 (17.07.75)	
A	Derwent Abstract Accession No. F3091A/27, class R21, SU,A, 570003 (GORKI RADIO PHYSICS) 20 September 1977 (20.09.77)	
	(continued)	

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
26 July 1990 (26.07.90)	3 August 1990
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	M.E. DIXON

FURTHER INFORMATION CONTI[illegible]ED FROM THE SECOND SHEET

A	Derwent Abstract Accession No. M8212D/50, Class P81, SU,A, 809025 (GORKI RADIO PHYSICS) 28 February 1981 (28.02.81)	
A,P	Patents Abstracts f Japan, P913, page 135, JP,A, 1-113626 (TOYO COMMUN EQUIP CO LTD) 2 May 1989 (02.05.89)	
A,P	Patents Abstracts of Japan, P974, page 125, JP,A, 1-233418 (NIPPON TELEGR & TELEPH CORP NIPPON TELEGRAPH AND TELEPHONE PUBLIC CORPORATION) 19 SEPTEMBER 1989 (19.09.89)	
A,P	Patents Abstracts of Japan, P979, page 24, JP,A, 1-241502 (NAMIKI PRECISION JEWEL CO LTD) 26 September 1989 (26.09.89)	
A,P	Patents Abstracts of Japan, P1002, page 129, JP,A, 1-287528 (TDK CORP) 20 November 1989 (20.11.89) (continued)	

V. [] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[] Claim numbers ..., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1. [] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. [] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. [] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[] The additional search fees were accompanied by applicant's protest.

[] No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDER[illegible] BE RELEVANT (CONTINUED FROM THE SECOND SE[illegible]

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A,P	Patents Abstracts of Japan p1004, page 144, JP,A, 1-291212 (NAMIKI PRECISION JEWEL CO LTD) 22 November 1989 (22.11.89)	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 90/00223

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
AU 1361/66	BE 677456 US 3438692	DE 1497631	NL 6602516
AU 64541/74	AT 319/74 FR 2231028 JP 49111649	CA 10018 72 GB 1410902 US 3868168	DE 2401973 IN 140816

END OF ANNEX